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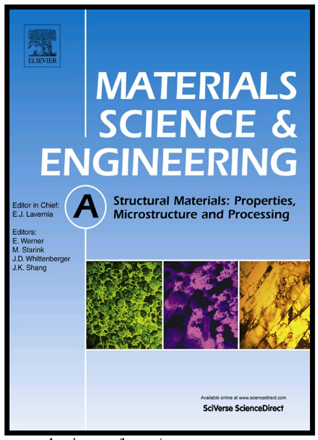

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Evaluation of hydrogen induced damage of steels by different test methods

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Abstract
The deleterious effect of hydrogen on mechanical properties of microalloyed pipeline (X70) and structural (S355) hot rolled steel strips was evaluated by static tensile testing of smooth and notched specimens (flat specimens with a central hole) and Charpy V impact testing. Hydrogen induced changes of the fatigue crack growth behavior were also examined. Most of the tests were performed on specimens exposed to the ageing for 4-years as well as on specimens who were after four years of ageing electrolytically charged with hydrogen. The comparison of mechanical properties of both studied steels before and after hydrogen charging showed that the degradation effect of hydrogen may or may not be detected, depending on the conditions of testing. The effect of hydrogen on the development of local plastic strain during deformation and fracture process as well as plastic zone size around the holes, notches and cracks observed on surface specimens was studied by differential interference contrast in optical microscope. The most important result of this work was the finding that the plastic zone size at the tip of the growing fatigue crack observed on the surface of hydrogenated specimens was significantly larger than for nonhydrogenated specimens.

Keywords-
low carbon steel, mechanical properties, aging, hydrogen embrittlement, plastic zone

1. Introduction

It is well known that the interstitial atoms such as hydrogen (H), carbon (C) and nitrogen (N) can expressively modify the physical, chemical and mechanical properties of materials [1,2]. The characteristic feature of their effect is time dependent change of mechanical properties of steels due to the ability of the H, C and N atoms to migrate through the lattice at ambient temperature. Although the solubility of H in the α-Fe lattice is much lower in comparison with C and N, his mobility is the highest because of the smallest atomic radius [3]. This is one of the main reasons why degrading effects of H are much more complicated and often ambiguous. The degradation effect of C and N on the properties of steels is usually associated with aging of steels accompanied by increase (bar none) in hardness/strength, and decrease in ductility resulting in a deterioration of cold formability and/or toughness [4-6]. In contrast, depending on the type of steel and many other variables (such as test temperature, strain rate, level and type of stress, ...), the presence of H may cause both softening as well as hardening (increase or decrease of yield strength and/or tensile strength) [7-9]. It is generally recognized that the sensitivity to the H-induced failure or hydrogen embrittlement (HE, defined as a process resulting in decrease of the ductility of the material) increases with increasing strength levels of steel. However, the susceptibility of the steels to HE can be significantly influenced also by the microstructure [10-12]. On the other hand, the ambiguous influence of both the strength and microstructure on HE susceptibility of 34 different steel grades having yield stress in the range of approximately 250-1100 MPa, was reported by Barnoush [13] or other works [14,15]. Based on the fact that the atomic H in metals can exist